

## REMARKS

Claims 1-3, 7 and 12-21 were pending in this application.

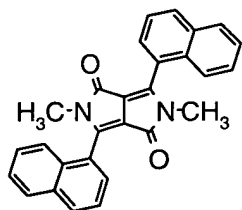
Claims 1-6, 8-12 and 18-21 are cancelled.

Claims 7 and 13 are amended.

Claims 7 and 13-17 are now pending.

Applicants have selected Group II reading on claims 7 and 13-17. The Applicants have further selected the species of formula (I) in which each of  $R_1$  and  $R_2$  is  $C_{1-25}$  alkyl and each of  $Ar_1$  and  $Ar_2$  is substituted or unsubstituted naphthyl reading on claims 7 and 13 only.

The ultimate species selection for search purposes is



The Applicants stated in the September 3, 2003 paper that the ultimate species reads on claims 7 and 13. This is incorrect. The above ultimate species reads only on claim 13. Note the proviso at the end of claim 7 that  $R_6$  and  $R_7$  do not stand simultaneously for hydrogen.

### **35 U.S.C. 112, second paragraph**

Claim 7 is rejected under 35 U.S.C. 112, second paragraph, as being indefinite.

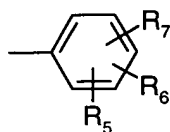
Applicants have amended as suggested by the Examiner and clarified the term "aryl" within claim 7:

Applicants have amended claim 7 by changing "aryl" to  $C_6-C_{24}$ -aryl. The definition of  $C_6-C_{24}$ -aryl can be found on page 18, paragraph 3 of the specification. The amendment is a self-evident one since the

term “aryl” can only refer back to the more specific term “C<sub>6</sub>-C<sub>24</sub>-aryl”, since this is the only place where the term “aryl” occurs in claim 7.

Whenever “n” or “m” appears within claim 7, Applicants have amended to include definitions of both so that it is clear what is meant by “n” and “m”.

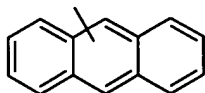
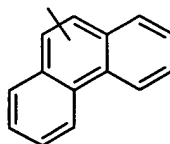
Further, Applicants have amended the self-evident error to the formula for a phenyl group as a possibility for Ar<sub>1</sub> and Ar<sub>2</sub> of formula III



by replacing one of the R<sub>7</sub> designations by R<sub>5</sub> to conform with the definitions

Applicants have clarified the meaning of n, R<sub>8</sub>, R<sub>9</sub>, R<sub>10</sub> and the proviso for R<sub>6</sub> and R<sub>7</sub> at the end of claim 7 by stating explicitly what is meant.

Applicants have amended claim 7 by deleting the structures



and replacing with phenanthryl and anthryl respectively.

Claim 13 is amended to add a period at the end of the claim, addition of the connector “and” , and commas separating all of the structures in claim 13. No new matter has been added.

The Applicants submit that all of the 35 USC 112, second paragraph rejections are overcome and asks that the Examiner reconsider.

### **Obviousness-Type Double Patenting**

Claims 7 and 13 are rejected under the judicially created doctrine of obviousness-type double patenting as being unpatentable over claims 1,2,4 and 5 of U.S. Patent No. 6,603,020. The Applicants are enclosing a terminal disclaimer to overcome the rejection.

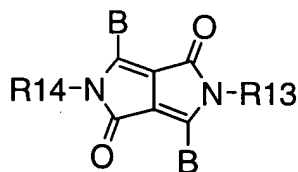
### 35 U.S.C. 103(a)

Claims 7 and 13 are rejected under 35 U.S.C. 103(a) as being unpatentable over Jost et al. US 4,585,878. Examiner alleges is would have been *prima facie* obvious to one of ordinary skill in the art at the time of the invention to make various compounds within the scope of Jost's formula (I) in order to provide compounds useful for Jost's purposes. The Applicants respectfully disagree.

Jost exemplifies structures wherein Ar<sub>1</sub> and Ar<sub>2</sub> are phenyl only. Substitution on the nitrogen exemplified shows only alkyl or hydrogen. Claim 7 of the instant invention does not encompass compounds wherein Ar<sub>1</sub> and Ar<sub>2</sub> are phenyl.

Furthermore, the compounds of the instant invention show unexpected properties not recognized or suggested by Jost as shown by Japanese application number JP A2001-257078 by Toray. This application describes the use of DPP compounds in EL devices with particular Ar<sub>1</sub> and Ar<sub>2</sub> substitution. The Applicants have enclosed an English translation of JP-A-2001-25708 herewith. The patent was published September 21, 2001, almost one year after the Applicants filing date and therefore is not prior art. JP '078 discloses data that clearly show that naphthyl substitution for Ar<sub>1</sub> and Ar<sub>2</sub> is superior to the phenyl substitution as exemplified in Jost.

JP-A-2001-257078 (Toray) describes



**B = 1-naphthyl**

Example	R13 = R14	Compound	$\lambda$ [nm]	EL [Cd/m <sup>2</sup> ]	Page of JP '708
1	Benzyl	EM1	558	4920	26
2	4-tBu-benzyl	EM2	560	5330	27
3	1-naphthyl	EM3	564	4900	27

4	Ethyl	EM4	567	5000	28
5	4-methylbenzyl	EM5	556	7240	28

**B= phenanthryl**

6	4-methylbenzyl	EM6	563	16940	29
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**B= phenyl**

8	4-methylbenzyl	EM8	582	133	30
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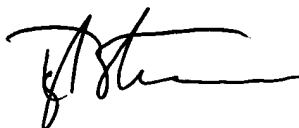
The electroluminescent intensity is unexpectedly increased in DPP compounds when phenyl is replaced by naphthyl or phenanthryl. Therefore Applicants instant invention shows unexpected advantages to those exemplified by Jost.

Reconsideration and withdrawal of the rejection of claims 7 and 13-17 is respectfully solicited in light of the remarks and amendments *supra*.

Since there are no other grounds of objection or rejection, passage of this application to issue with claims 7 and 13-17 is earnestly solicited.

In the event that minor amendments will further prosecution, Applicants request that the examiner contact the undersigned representative.

Respectfully submitted,

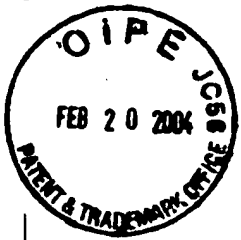


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Enclosure: Terminal disclaimer, translation of Japanese patent JP-A-2001-257078,  
Fee letter

FEB 18 2004



FEB 27 2004

PATENT LAID-OPEN (A)

No. 2001-257078

September 21, 2001

Title: Heat-sensitive recording medium  
Application No.: 2000-397145 (P2000-397145)  
Filing date: December 27, 2000  
Inventor: T. Tominaga  
Inventor: D. Kitazawa  
Inventor: A. Takano  
Inventor: S. Murase  
Applicant: Toray Industries, Inc.  
Intl.Cl.<sup>7</sup>: H05B 33/14  
C09K 11/06 610  
650  
H05B 33/22

[TITLE OF THE INVENTION] Light Emitting Element

[DETAILED DESCRIPTION OF THE INVENTION]

[0001]

[Technical Field to which the Invention Belongs]

The present invention relates to a light emitting element capable of converting electrical energy into light that can be used in fields such as display elements, flat panel displays, back lighting, illumination, interior lighting, signs, billboards, electronic photographic machines and optical signal generators.

[0002]

[Prior Art]

Considerable research has been actively conducted in recent years on organic laminated thin film light emitting elements that emit light when electrons injected from a cathode and positive holes injected from an anode are re-coupled in an organic fluorescent material positioned

between both electrodes. This element is attracting attention due to its characteristics of being thin, emitting light of high luminance at a low driving voltage, and emitting multi-colored light depending on the fluorescent material selected.

[0003]

Ever since C. W. Tang of the Kodak Corp. demonstrated that an organic laminated thin film element emits light of high luminance (Appl. Phys. Lett. 51 (12)21, p. 913, 1987), numerous research institutes have conducted studies on this research. The typical constitution of the organic laminated thin film light emitting element proposed by the Kodak research group consists of sequentially providing a diamine compound capable of transporting positive holes, a tris(8-quinolinolate) aluminum complex serving as the light emitting layer, and Mg and Ag serving as the cathode on an ITO glass substrate, and this element was capable of emitting green light of  $1000 \text{ cd/m}^2$  at a driving voltage of about 10 V. In addition to the above element constituents, although current organic laminated thin film light emitting elements have different constitutions such as the providing of an additional electron transport layer, they are still fundamentally based on the constitution of the Kodak Corp.

[0004]

Of all the researches on the emission of multiple colors of light, research on materials emitting green light has been the most active. At present, there is a growing demand for materials emitting red light as well as those emitting blue light that have superior durability and are able to demonstrate adequate luminance and color purity characteristics, and earnest research is being conducted with the aim of improving the characteristics.

[0005]

[Problems to be Solved by the Invention]

However, many of the light emitting materials used in

the prior art (host materials and dopant materials) have low light emission efficiency, high power consumption, low durability and short element life. In addition, even though they have strong fluorescent intensity in the solution state, when in the form of a thin film, fluorescent intensity decreases remarkably due to concentration extinction and exciplex or excimer formation, and many were unable to allow the obtaining of high luminance light emission when applied to light emitting elements.

[0006]

With respect to the emission of red light in particular, although a host material having a long wavelength emission (yellow to orange) is desirable in order to obtain emitted light having high color purity, the extremely small number of substances capable of realizing both long wavelength emission and high luminance has been a major problem.

[0007]

In order to solve the above problems, the object of the present invention is to provide a light emitting element having high electrical energy utilization efficiency and high luminance.

[0008]

[Means for Solving the Problems]

The present invention discloses a light emitting element that emits light by electrical energy by having a luminous substance between an anode and a cathode, wherein said element at least contains a compound represented by the following general formula (1):

[0009]

[Chemical 5]



[0010]

(wherein A represents an organic fluorescent backbone, B represents a substitution group for which the isotropic rotation relative to A is limited by the steric repulsion between A and B or between B and B, and n represents a natural number between 1 and 4).

[0011]

[Mode for Carrying Out the Invention]

In the present invention, although there are no particular restrictions on the anode provided it is transparent for extracting light, examples of which include an electrically conductive metal oxide such as tin oxide, indium oxide or indium tin oxide (ITO), metal such as gold, silver or chromium, inorganic electrically conductive substance such as copper iodide or copper sulfide, or electrically conductive polymer such as polythiophene, polypyrrole or polyaniline, the use of ITO glass or Nesa glass is particularly preferable. Although there are no particular restrictions on the resistance of the transparent electrode provided it is capable of supplying adequate current light emission by the element, resistance is preferably low from the viewpoint of power consumption of the element. For example, although an ITO substrate having resistance of 300  $\Omega$ / or less functions as an element electrode, since it is currently possible to provide substrates having resistance of about 10  $\Omega$ /, the use of a low resistance electrode is particularly preferable. Although the ITO thickness can be arbitrarily selected according to the resistance value, a thickness of between 100 and 300 nm is normally used in the majority of cases. In addition, soda lime glass, non-alkaline glass and so forth are used for the glass substrate, and since the thickness should be that which is adequate for maintaining mechanical strength, a thickness of 0.5 mm or



more is adequate. With respect to the material of the glass, although non-alkaline glass is preferable since it is preferable that the level of ions eluted from the glass be low, since soda lime glass barrier-coated with  $\text{SiO}_2$  and so forth is also commercially available, this can also be used. There are also no particular restrictions on the method for forming the ITO film, examples of which include the electron beam, sputtering and chemical reaction methods.

[0012]

Although there are no particular restrictions on the cathode provided it is a substance that allows electrons to be efficiently injected into the present organic layer, and typical examples include platinum, gold, silver, copper, iron, tin, zinc, aluminum, indium, chromium, lithium, sodium, potassium, calcium and magnesium, alloys containing lithium, sodium, potassium, calcium, magnesium, or other metals having low work functions are effective for increasing electron injection efficiency and improving element characteristics. However, since many of these low work function metals are typically unstable in the air, and although a method for using a highly stable electrode by doping an organic layer with a trace amount of lithium or magnesium (1 nm or less as indicated with a film thickness gauge in vacuum deposition) is a preferable example of this, since it is also possible to use an inorganic salt like lithium fluoride, the cathode is not particularly limited to these. Moreover, preferable examples for protecting the electrode include the lamination of a metal such as platinum, gold, silver, copper, iron, tin, aluminum or indium, an alloy using these metals, an inorganic substance such as silica, titania or silicon nitride, or a hydrocarbon-based polymer such as polyvinyl alcohol or vinyl chloride. There are also no particular restrictions on the production methods of these electrodes provided they

allow the passage of current, examples of which include electron beam, sputtering, ion plating and coating methods.  
[0013]

The form of the luminous substance in the present invention refers to any of 1) positive hole transport layer/light emitting layer, 2) positive hole transport layer/light emitting layer/electron transport layer, 3) light emitting layer/electron transport layer, 4) positive hole transport layer/light emitting layer/positive hole blocking layer, 5) positive hole transport layer/light emitting layer/positive hole blocking layer/electron transport layer, 6) light emitting layer/positive hole blocking layer/electron transport layer, and 7) mixing of the above combinations of substances into a single layer. Namely, in addition to the multi-layer laminated structures of 1) through 6) above, one layer containing a light emitting material alone or a light emitting material, positive hole transport material and electron transport material in the manner of 7) above may be provided for the element constitution. Moreover, the luminous substance of the present invention includes that which emits light on its own or that which assists in the emission of light, and refers to compounds or layers and so forth that are involved in the emission of light.

[0014]

The positive hole transport layer is formed by a positive hole transport substance alone or by laminating and mixing two or more types of substances or by a mixture of a positive hole transport substance and a polymer binding agent, and although preferable examples of positive hole transport substances include triphenylamines such as N,N'-diphenyl-N,N'-di(3-methylphenyl)-4,4'-diphenyl-1,1'-diamine and N,N'-dinaphthyl-N,N'-diphenyl-4,4'-diphenyl-1,1'-diamine, bis(N-allylcarbazoles) or bis(N-alkylcarbazoles), heterocyclic compounds represented by

pyrazoline derivatives, stilbene compounds, hydrazone compounds, oxadiazole derivatives and phthalocyanine derivatives and porphyrin derivatives, as well as polymer-based compounds such as polycarbonate and styrene derivatives, polyvinylcarbazole and polysilane having the above monomers in their side chains, there are no particular restrictions on these provided they are compounds that allow formation of the required thin film for producing the element, allow positive holes to be injected from the anode, and are capable of transporting positive holes.

[0015]

The light emitting layer is formed from a light emitting material (host material, dopant material), and this may be a mixture of host material and dopant material, or may consist of host material only. The host material and dopant material may be of one type each, or a plurality of types may be used in combination. The dopant material may also be contained throughout the host material or only in a portion thereof. The dopant material may also be laminated or dispersed.

[0016]

A compound represented by general formula (1) below is preferably used for the light emitting material since it allows the obtaining of highly luminous emission of light.

[0017]

[Chemical 6]



[0018]

Here, A represents an organic fluorescent backbone, B represents a substitution group in which the isotropic rotation relative to A is restricted by steric repulsion between A and B or between B and B, and n represents a

natural number between 1 and 4.

[0019]

A of general formula (1) can be selected according to the desired color of the emitted light. Although there are no particular restrictions on A, in order to obtain highly luminous emission of light, examples of substances that are used preferably due to their high fluorescent quantum yield include aromatic hydrocarbon compounds such as naphthalene, anthracene, phenanthrene, pyrene, triphenylene, perylene, truxene, fluorene, indene, 9,9'-spirobifluorene, distyrylbenzene derivatives, tetraphenylbutadiene derivatives and stilbene derivatives, and aromatic heterocyclic compounds such as furan, pyrrole, thiophene, silole, 9-silafluorene, 9,9'-spirobisilafluorene, triazole, oxadiazole, benzothiophene, benzofuran, indole, dibenzothiophene, dibenzofuran, carbazole, benzoxazole, benzimidazole, benzthiazole, benzdioxazole, benzdiimidazole, benzdithiazole, phenanthroimidazole, phenanthrooxazole, imadazopyridine, phenanthroline, pyrazine, naphthilazine, quinoxaline, pyrrolopyridine, pyrimidine, thioxantene, aldazine, coumarin, phthalimide, naphthalimide, perynone and pyrimidopyrimidine. Moreover, various types of metal complexes having ligands such as quinolinol, benzquinolinol, benzoxazole, benzimidazole, triazole or azomethin may also be used for A of general formula (1).

[0020]

B of general formula (1) is a substitution group that fulfills the role of retaining the superior fluorescent characteristics of A of general formula (1) in the state of a thin film and allows highly luminous light emission in the light emitting element. Namely, since B forms a substitution group in which isotropic rotation relative to A is restricted by steric repulsion between A and B or between B and B, it decreases the probability of excitation

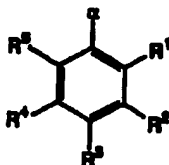
energy in the thin film state being thermally deactivated by rotation of substitution groups, thereby preventing a decrease in fluorescent quantum yield. In addition, since B is able to twist relative to A, it prevents stacking of corresponding light emitting material molecules, making it possible to suppress concentration extinction as well as exciplex or excimer formation. As a result, emitted light of high luminance and high color purity can be obtained in the light emitting element. The restricting of isotropic rotation can be easily confirmed by molecular models and molecular calculations.

[0021]

Although the above isotropic rotation may be restricted by steric repulsion between A and B or between B and B, it is preferably restricted by steric repulsion between A and B in order to obtain emitted light of higher luminance. A substitution group having the backbone shown in general formula (2) below is preferably used for B having the above effects.

[0022]

[Chemical 7]



(2)

[0023]

Here,  $R^1$  through  $R^5$  may be the same or different, and are selected from a hydrogen, alkyl group, cycloalkyl group, aralkyl group, alkenyl group, cycloalkenyl group, alkynyl group, hydroxyl group, mercapto group, alkoxy group, alkylthio group, arylether group, arylthioether group, aryl group, heterocyclic group, halogen, haloalkane, haloalkene, haloalkyne, cyano group, aldehyde group,

carbonyl group, carboxyl group, ester group, carbamoyl group, amino group, nitro group, silyl group, siloxanyl group and a condensed ring or aliphatic ring formed with adjacent substitution groups. However, at least one of  $R^1$  and  $R^5$  is either a substitution group other than hydrogen or forms a condensed ring or aliphatic ring with adjacent substitution groups.  $\alpha$  indicates the coupling site with the above-mentioned A.

[0024]

Among these substitution groups, an alkyl group indicates a saturated aliphatic hydrocarbon group such as a methyl group, ethyl group, propyl group or butyl group that may or may not be substituted. In addition, a cycloalkyl group indicates a saturated alicyclic hydrocarbon group such as a cyclopropyl group, cyclohexyl group, norbornyl group or adamantyl group that may or may not be substituted. In addition, an aralkyl group indicates an aromatic hydrocarbon group mediated by an aliphatic hydrocarbon group such as a benzyl group or phenylethyl group, and both the aliphatic hydrocarbon group and aromatic hydrocarbon group may or may not be substituted. In addition, an alkenyl group indicates an unsaturated aliphatic hydrocarbon group that contains a double bond such as a vinyl group, allyl group or butadienyl group that may or may not be substituted. In addition, a cycloalkenyl group indicates an unsaturated alicyclic hydrocarbon group that contains a double bond such as a cyclopentenyl group, cyclopentadienyl group or cyclohexene group that may or may not be substituted. In addition, an alkynyl group indicates an unsaturated aliphatic hydrocarbon group that contains a triple bond such as an acetylenyl group that may or may not be substituted. In addition, an alkoxy group indicates an aliphatic hydrocarbon group mediated by an ether bond such as a methoxy group, and the aliphatic

hydrocarbon group may or may not be substituted. In addition, an alkylthio group indicates a group in which an oxygen atom of an ether bond of an alkoxy group is substituted with a sulfur atom. In addition, an aryether group indicates an aromatic hydrocarbon group mediated by an ether bond such as a phenoxy group, and the aromatic hydrocarbon group may or may not be substituted. In addition, an arylthioether group indicates a group in which an oxygen atom of an ether bond of an aryether group is substituted with a sulfur atom. In addition, an aryl group indicates an aromatic hydrocarbon group such as a phenyl group, naphthyl group, biphenyl group, phenanthryl group, terphenyl group or pyrenyl group that may or may not be substituted. In addition, a heterocyclic group indicates a cyclic structure group having an atom other than carbon such as a furyl group, thienyl group, oxazolyl group, pyridyl group, quinolyl group or carbazolyl group that may or may not be substituted. A halogen indicates fluorine, chlorine, bromine or iodine. A haloalkane, haloalkene or haloalkyne indicates a group such as a trifluoromethyl group in which all or a portion of the above alkyl group, alkenyl group or alkynyl group is substituted with a previously mentioned halogen, while the remainder may or may not be substituted. An aldehyde group, carbonyl group, ester group, carbamoyl group or amino group includes a group that has been substituted with an aliphatic hydrocarbon, alicyclic hydrocarbon, aromatic hydrocarbon or heterocyclic group, and the aliphatic hydrocarbon, alicyclic hydrocarbon, aromatic hydrocarbon or heterocyclic group may or may not be substituted. A silyl group indicates a silicon compound group such as a trimethylsilyl group that may or may not be substituted. A siloxanyl group indicates a silicon compound group mediated by an ether bond such as a trimethylsiloxanyl group that may or may not be substituted. The condensed ring or aliphatic

ring formed with adjacent substitution groups may or may not be substituted.

[0025]

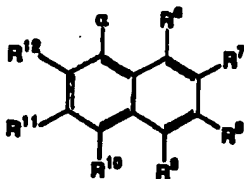
Since at least one of  $R^1$  and  $R^5$  of general formula (1) is either a substitution group other than hydrogen or forms a condensed ring or aliphatic ring between adjacent substitution groups, steric repulsion occurs with the above A, and isotropic rotation of B relative to A is restricted.

[0026]

Moreover, in order to obtain stable emission of highly luminous light, it is preferable for superior stability that at least one of the above  $R^1$  and  $R^5$  form a condensed ring with adjacent substitution groups. Thus, a substitution group having the backbone shown in general formula (3) below is preferably used for the above B.

[0027]

[Chemical 8]



(3)

[0028]

Here,  $R^6$  through  $R^{12}$  may be the same or different, and are selected from a hydrogen atom, alkyl group, cycloalkyl group, aralkyl group, alkenyl group, cycloalkenyl group, alkynyl group, hydroxyl group, mercapto group, alkoxy group, alkylthio group, arylether group, arylthioether group, aryl group, heterocyclic group, halogen, haloalkane, haloalkene, haloalkyne, cyano group, aldehyde group, carbonyl group, carboxyl group, ester group, carbamoyl group, amino group, nitro group, silyl group, siloxanyl group, and condensed ring and aliphatic ring formed with adjacent substitution groups.  $\alpha$  indicates the coupling



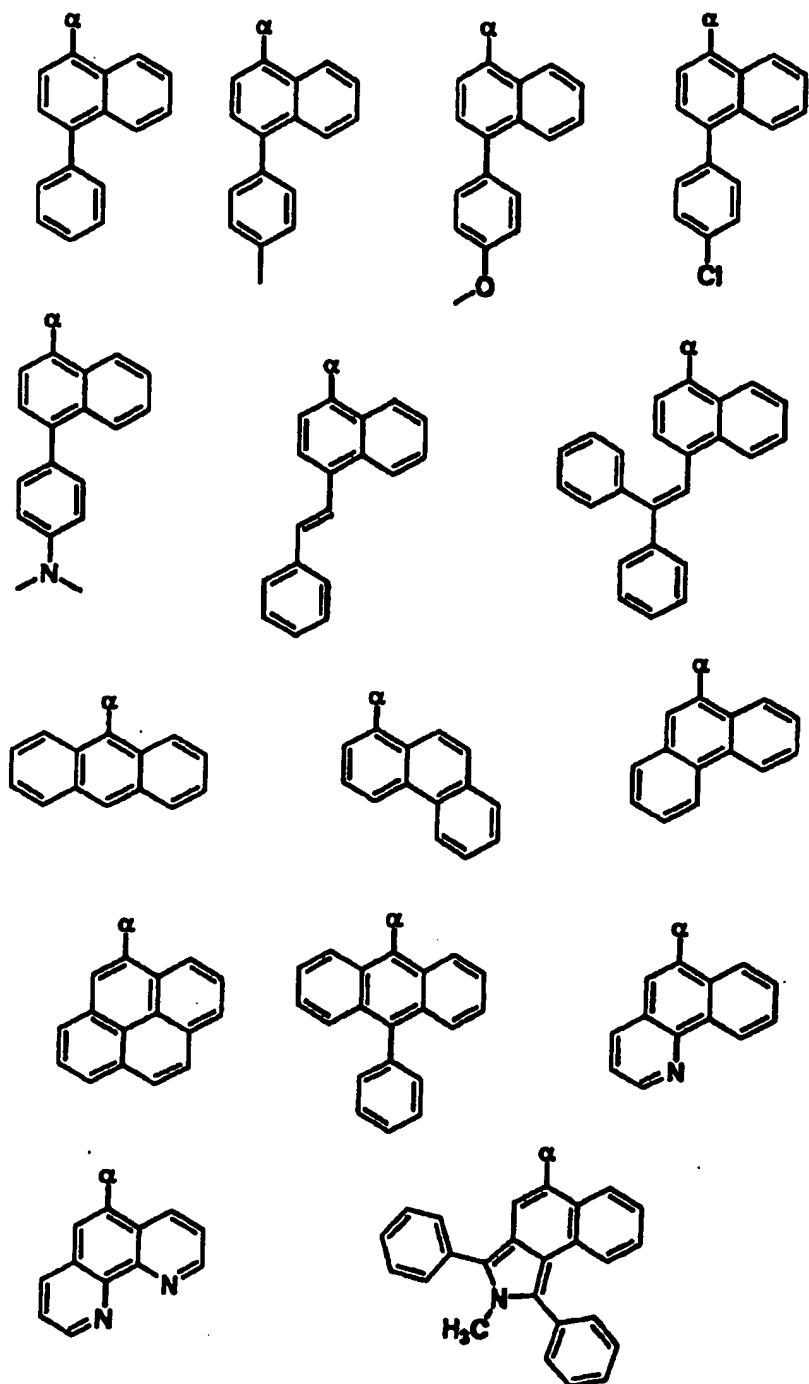
site with the above-mentioned A. The explanation of these substitution groups is the same as that previously described.

[0029]

Although there are no particular restrictions on preferable examples of the above B, examples of specific structures are indicated below.

[0030]

[Chemical 9]



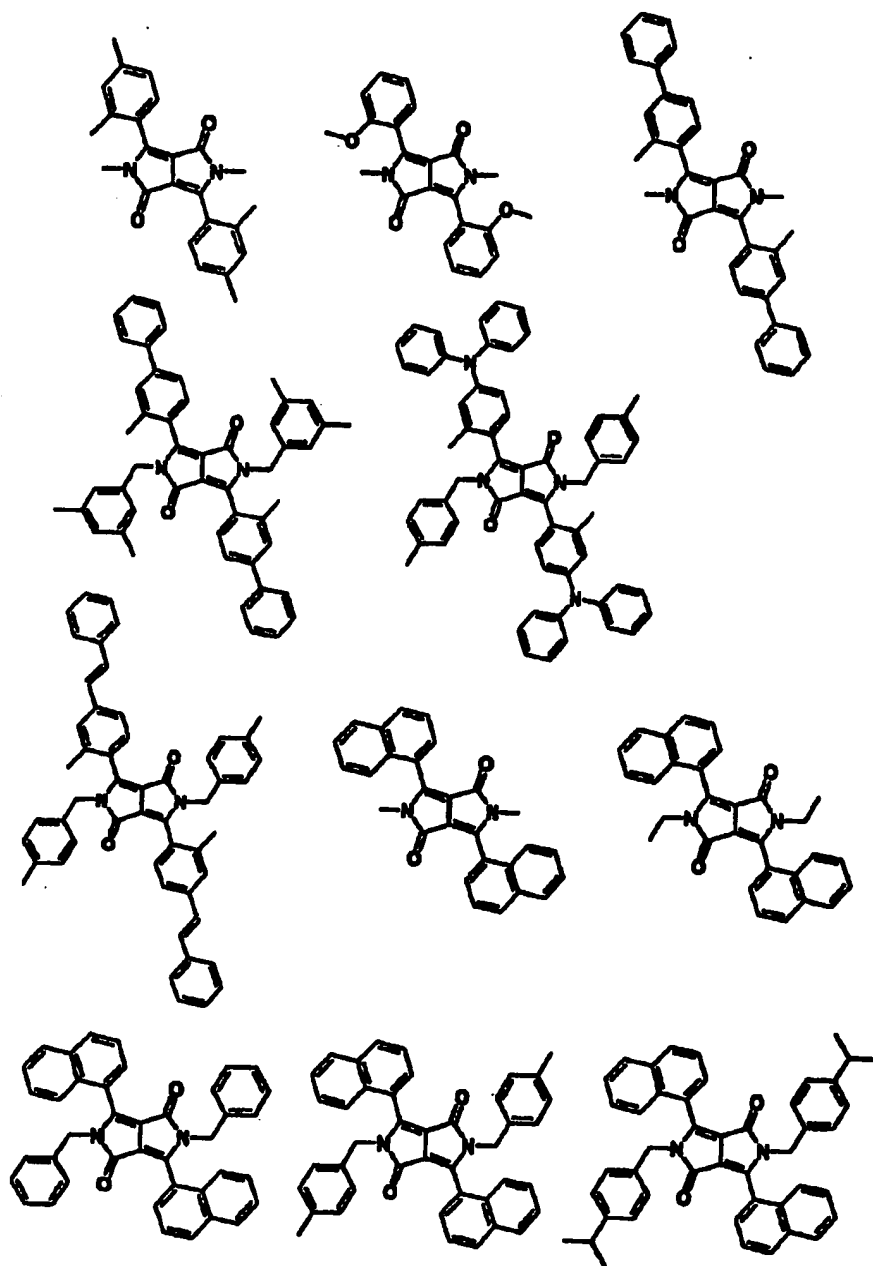
[0032]

Although the red material of the present invention can be preferably used as a blue light emitting material and

those compounds are indicated below.

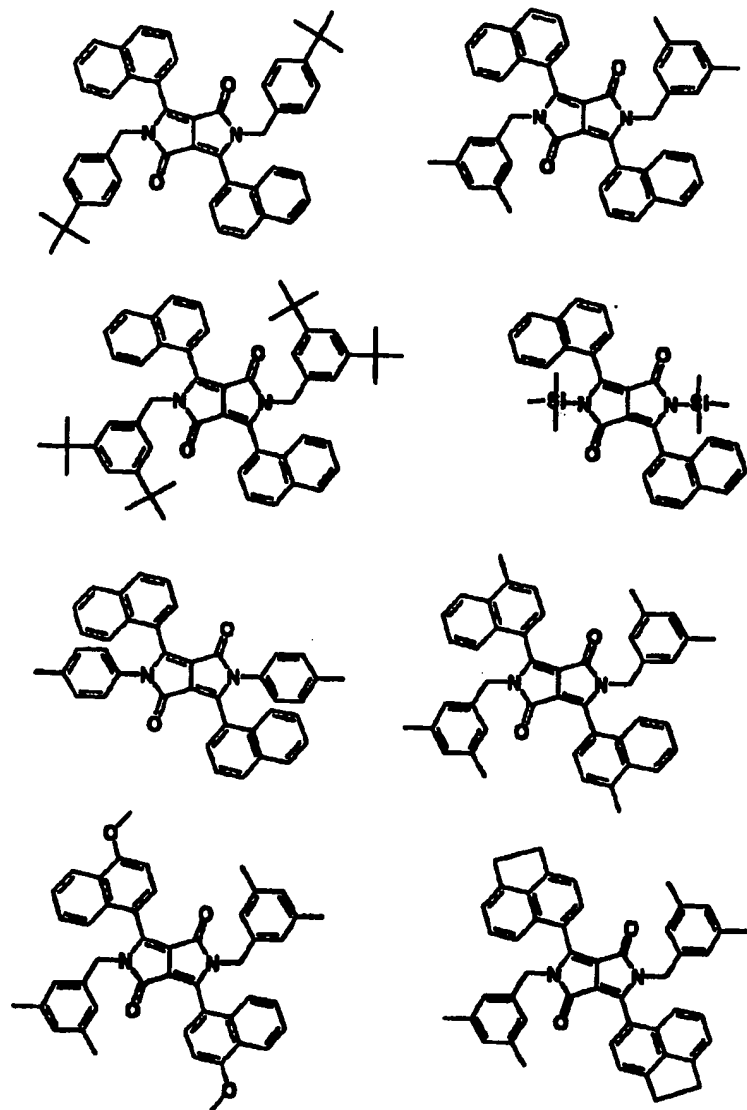
[0037]

[Chemical 12]



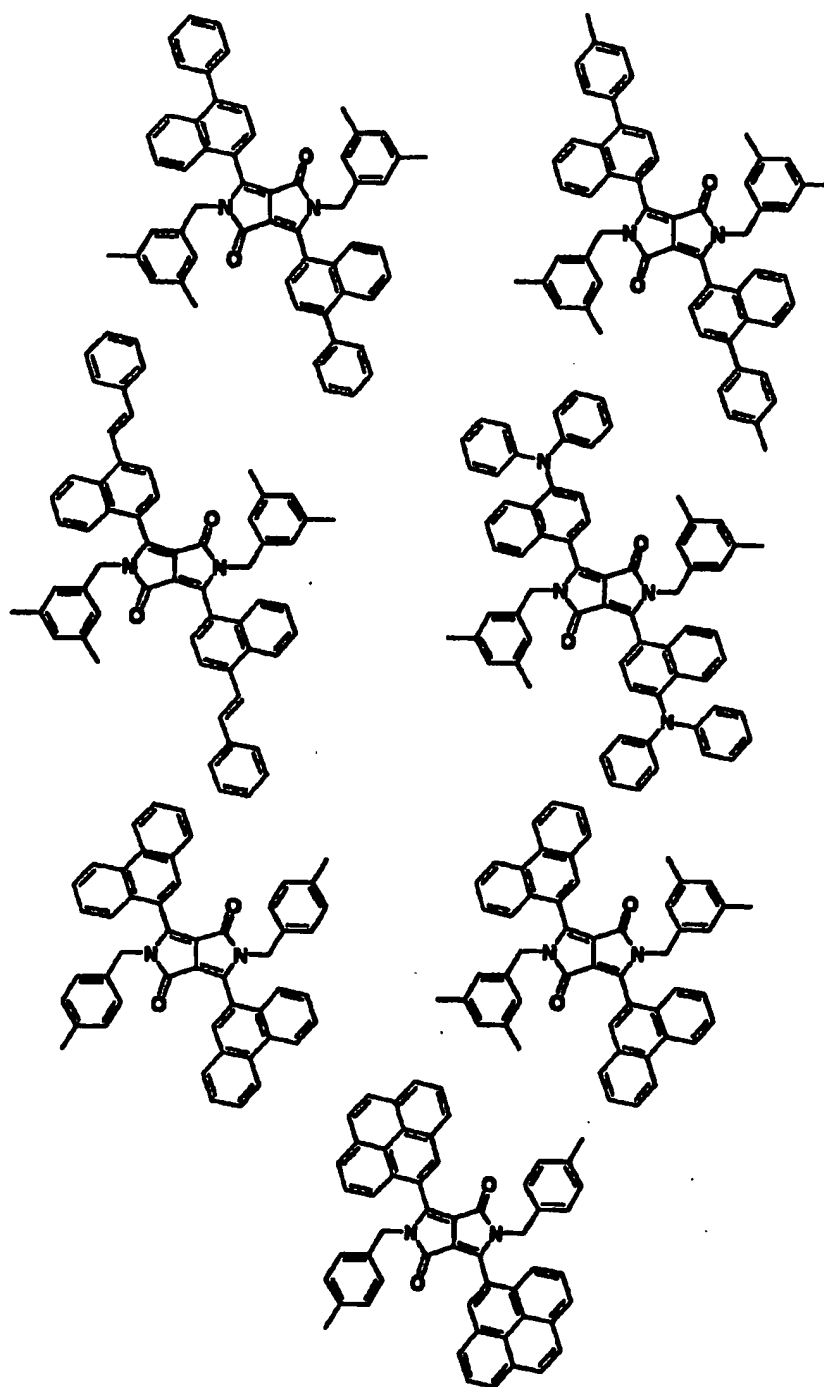
[0038]

[Chemical 13]



[0039]

[Chemical 14]



[0040]

Although the light emitting material of the present invention may be used as a host material or dopant

material, since it is able to maintain superior fluorescent characteristics even in the state of a thin film, it is more preferably used as a host material. In this case, emission of light of high color purity can be obtained by using another organic fluorescent compound for the dopant material. Examples of dopant materials include condensed ring derivatives such as pyrene, tetracene, pentacene, perylene, naphthopyrene, dibenzopyrene and rubrene, azole derivatives such as oxazole, benzazole derivatives such as benzoxazole, diazole derivatives such as oxadiazole, pyrazoline derivatives, stilbene derivatives, thiophene derivatives, tetraphenylbutadiene derivatives, cyclopentadiene derivatives, bisstyryl derivatives such as bisstyrylanthracene derivatives and distyrylbenzene derivatives, furan derivatives, benzofuran derivatives, isobenzofuran derivatives, dibenzofuran derivatives, coumarin derivatives such as 7-dialkylaminocoumarin derivatives, 7-piperidinocoumarin derivatives, 7-hydroxycoumarin derivatives, 7-methoxycoumarin derivatives, 7-acetoxycoumarin derivatives, 3-benzthiazolylcoumarin derivatives, 3-benzimidazolylcoumarin derivatives, 3-benzoxazolylcoumarin derivatives, dicyanomethylenepyrane derivatives, dicyanomethylenethiopyrane derivatives, polymethin derivatives, cyanine derivatives, oxobenzanthracene derivatives, xanthene derivatives, rhodamine derivatives, fluoresceine derivatives, pyrylium derivatives, carbostyryl derivatives, acridine derivatives, oxazine derivatives, phenylene oxide derivatives, quinacridone derivatives, quinazoline derivatives, pyrrolopyridine derivatives, flopyridine derivatives, 1,2,5-thiaziazolopyrene derivatives, perynone derivatives, pyrrolopyrrole derivatives, squarylium derivatives, violanthrone derivatives, phenazine derivatives, acridone derivatives and diazaflavin derivatives.

[0041]

In order to obtain red light emission by combining with the light emitting material of the present invention in particular, the dopant material preferably has red fluorescence, and although specific examples of the prior art that can be used include naphthalimide derivatives such as bis(diisopropylphenyl)perylene-tetracarboxylate imide, perynone derivatives, rare earth complexes such as Eu complexes having for their ligand acetyl acetone, benzoyl acetone or phenanthroline, 4-(dicyanomethylene)-2-methyl-6-(p-dimethylaminostyryl)-4H-pyrene and its analogues, metal phthalocyanine derivatives such as magnesium phthalocyanine and aluminum chlorophthalocyanine, rhodamine compounds, diazaflavin derivatives, coumarin derivatives, oxazine compounds and phenoxazine derivatives, they are not particularly restricted to these dopant materials.

[0042]

Since the concentration extinction phenomenon normally occurs if the doped amount is too high, normally the amount of dopant material is preferably used at 10 wt% or less, and more preferably at 2 wt% or less, relative to the host material. With respect to the doping method, although the light emitting material can be formed by co-vapor deposition with the host material, the dopant material may be first mixed with the host material and then deposited simultaneously. In addition, since the dopant material emits light even in extremely small amounts, the dopant material can also be used by sandwiching a trace amount of dopant material between the host material. In this case, a single layer or two or more layers of host material may be laminated.

[0043]

The electron transport material in the present invention is required to efficiently transport electrons from the negative electrode between electrodes to which an electric field has been applied, and preferably has high

electron injection efficiency and efficiently transports injected electrons. Consequently, a substance is required that has large electron affinity, large electron mobility, superior stability and is resistant to the generation of impurities that become traps during its production and use. Although there are no particular restrictions on substances that satisfy these requirements, examples include quinolinol derivative metal complexes typically represented by tris(8-quinolinolate) aluminum complex, tropolone metal complexes, flavonol metal complexes, perylene derivatives, perynone derivatives, naphthalene, coumarin derivatives, oxadiazole derivatives, aldazine derivatives, bisstyryl derivatives, pyrazine derivatives, phenanthroline derivatives, silole derivatives, quinoxaline derivatives and boron compounds. Although these electron transport materials may be used alone, they may also be used by laminating or mixing with other electron transport materials.

[0044]

The positive hole blocking layer refers to a layer for preventing positive holes from moving from an anode between electrodes to which an electric field is applied without re-coupling with electrons from a cathode, and depending on the material that composes each layer, the re-coupling probability of positive holes and electrons is increased as a result of this layer being inserted, thereby making it possible to increase light emission efficiency. Although specific examples of such materials include phenanthroline derivatives, triazole derivatives and quinolinol metal complexes, there are no particular restrictions on the material provided it is a compound that is able to form a thin layer required for element production and efficiently block the movement of positive holes from the anode. Although these positive hole blocking materials may be used alone, they may also be used by laminating or mixing with a



different electron transport material.

[0045]

Although the materials used for the above positive hole transport layer, light emitting layer, electron transport layer and positive hole blocking layer are able to form each layer alone, they can also be used by dispersing in a polymer binding agent, examples of which include solvent-soluble resins such as polyvinyl chloride, polycarbonate, polystyrene, poly(N-vinylcarbazole), polymethylmethacrylate, polybutylmethacrylate, polyester, polysulfone, polyphenylene oxide, polybutadiene, hydrocarbon resin, ketone resin, phenoxy resin, polysulfone, polyamide, ethyl cellulose, vinyl acetate, ABS resin and polyurethane resin, as well as cured resins such as phenol resin, xylene resin, petroleum resin, urea resin, melamine resin, unsaturated polyester resin, alkyd resin, epoxy resin and silicone resin.

[0046]

Although there are no particular restrictions on the method of forming the luminous substance, examples of which include electron beam deposition, sputtering, molecular layering and coating, normally resistance heating deposition and electron beam deposition are preferable in terms of characteristics. Although there are no particular restrictions on layer thickness, which varies according to the resistance value of the luminous substance, it is selected from the range of 1 to 1000 nm.

[0047]

Although electrical energy mainly refers to direct current, pulsed current or alternating current may also be used. Although there are no particular restrictions on the current and voltage values, in consideration of the power consumption and service life of the element, maximum luminance should be attempted to be obtained with the lowest possible energy.

[0048]

The matrix in the present invention refers to that in which display pixels are arranged in the form of a matrix, and characters and images are displayed by gathering of those pixels. The shape and size of the pixels are determined according to the application. For example, square pixels measuring 300  $\mu\text{m}$  or less on a side are used for display images and characters on personal computers, monitors and televisions, while in the case of large displays such as display panels, pixels on the mm order per side are used. Although it is only required that pixels of the same color be arranged in rows in the case of monochromatic displays, in the case of color displays, images are displayed with rows of red, red, green and blue pixels. In this case, typical types include the delta type and striped type. In addition, the method for driving the matrix may be either linear sequential drive or active matrix drive. Although linear sequential drive offers the advantage of a simple structure, since there are cases in which active matrix drive is superior when considering operating characteristics, these must also be used according to the application.

[0049]

The segment type in the present invention refers to the formation of pattern so as to display predetermined information, and emitting light from a specified region. Examples of such segment types include the time and temperature displays of a digital watch or thermometer, the operating status display of audio equipment and electromagnetic cooking appliances, and the instrument panel display of an automobile. The above matrix display and segment display may coexist within the same panel.

[0050]

In addition, the light emitting element of the present

invention can also be preferably used as a back light. A back light refers to that which is primarily used for the purpose of improving the visibility of a display apparatus that does not emit light on its own, and is used in, for example, liquid crystal displays, clocks, audio equipment, automobile instrument panels, display panels and traffic signs. In consideration of the conventional back lighting used in liquid crystal displays, and particularly those used in personal computer applications requiring a thin design, that employed fluorescent lamps and light guides which made it difficult to achieve a thin design, the back light in the present invention is characterized by its thin design and light weight.

[0051]

[Examples]

Although the following provides an explanation of the present invention through its examples and comparative examples, the present invention is not limited to these examples.

[0052]

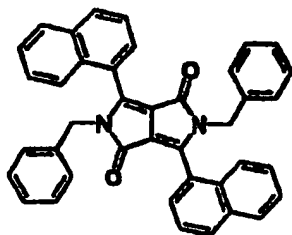
Example 1

A glass substrate on which ITO transparent conductive film was deposited to a thickness of 150 nm (Asahi Glass, 15  $\Omega$ / , electron beam deposition product) was cut to a size of 30 x 40 mm followed by etching. After subjecting the resulting substrate to ultrasonic cleaning for 15 minutes each in acetone and SemicoClean 56, it was rinsed with ultra-pure water. Continuously, the substrate was then subjected to ultrasonic cleaning for 15 minutes in isopropyl alcohol, immersed for 15 minutes in hot methanol and then allowed to dry. This substrate was treated with UV-ozone for 1 hour, placed in a vacuum deposition system and degassed until the vacuum in the system reached  $1 \times 10^{-5}$  Pa or less immediately before production of the

element. The positive hole transport material in the form of N,N'-diphenyl-N,N'-(3-methylphenyl)-1,1'-diphenyl-4,4'-diamine (TPD) was first deposited to a thickness of 50 nm by resistance heating to form the positive hole transport layer. Next, EM1 indicated below as the light emitting material was deposited to a thickness of 50 nm to form the light emitting layer. Next, lithium to a thickness of 0.5 nm and silver to a thickness of 150 nm were deposited to form the cathode and produce a 5 x 5 mm square element.

[0053]

[Chemical 15]



EM1

[0054]

Highly luminous light emission was obtained in which the peak emission wavelength of this light emitting element was 558 nm, and the maximum luminance was 4920 cd/m<sup>2</sup>.

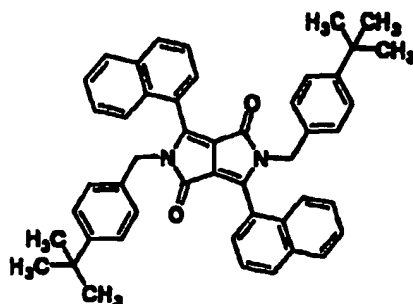
[0055]

Example 2

A light emitting element was produced in the same manner as Example 1 with the exception of using EM2 indicated below for the light emitting material.

[0056]

[Chemical 16]



EM2

[0057]

Highly luminous light emission was obtained in which the peak emission wavelength of this light emitting element was 560 nm, and the maximum luminance was 5330 cd/m<sup>2</sup>.

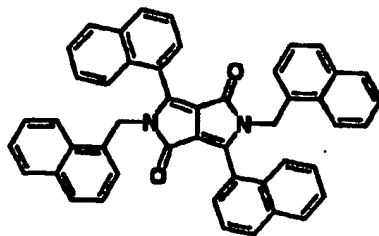
[0058]

Example 3

A light emitting element was produced in the same manner as Example 1 with the exception of using EM3 indicated below for the light emitting material.

[0059]

[Chemical 17]



EM3

[0060]

Highly luminous light emission was obtained in which the peak emission wavelength of this light emitting element was 564 nm, and the maximum luminance was 4900 cd/m<sup>2</sup>.

[0061]

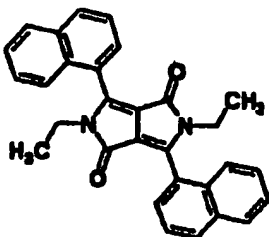
Example 4

A light emitting element was produced in the same manner as Example 1 with the exception of using EM4

indicated below for the light emitting material.

[0062]

[Chemical 18]



EM 4

[0063]

Highly luminous light emission was obtained in which the peak emission wavelength of this light emitting element was 567 nm, and the maximum luminance was 5000 cd/m<sup>2</sup>.

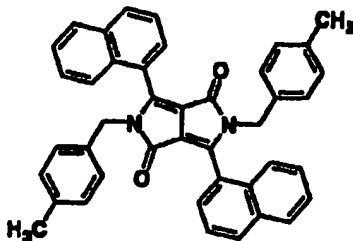
[0064]

Example 5

A light emitting element was produced in the same manner as Example 1 with the exception of using EM5 indicated below for the light emitting material.

[0065]

[Chemical 19]



EM 5

[0066]

Highly luminous light emission was obtained in which the peak emission wavelength of this light emitting element was 556 nm, and the maximum luminance was 7240 cd/m<sup>2</sup>.

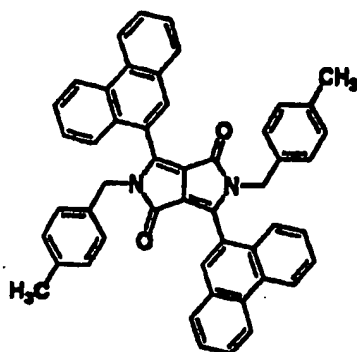
[0067]

Example 6

A light emitting element was produced in the same manner as Example 1 with the exception of using EM6 indicated below for the light emitting material.

[0068]

[Chemical 20]



EM6

[0069]

Highly luminous light emission was obtained in which the peak emission wavelength of this light emitting element was 563 nm, and the maximum luminance was 16940 cd/m<sup>2</sup>.

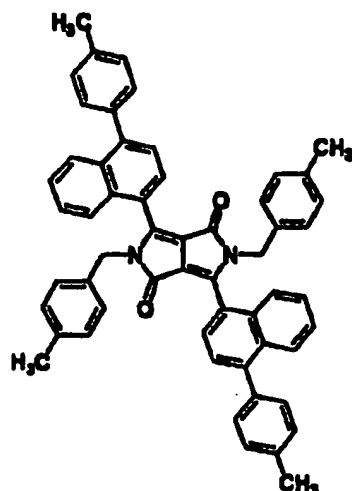
[0070]

Example 7

A light emitting element was produced in the same manner as Example 1 with the exception of using EM7 indicated below for the light emitting material. Highly luminous light emission was obtained in which the peak emission wavelength of this light emitting element was 588 nm, and the maximum luminance was 10000 cd/m<sup>2</sup>.

[0071]

[Chemical 21]



EM7

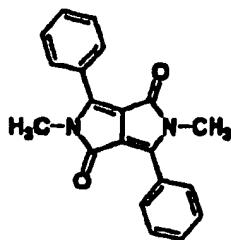
[0072]

Comparative Example 1

A light emitting element was produced in the same manner as Example 1 with the exception of using EM8 indicated below for the light emitting material. Only emission of light of low luminance was able to be obtained in which the peak emission wavelength of this light emitting element was 582 nm, and the maximum luminance was 133 cd/m<sup>2</sup>.

[0073]

[Chemical 22]



EM8

[0074]

[Effect of the Invention]

The present invention is able to provide a highly luminous light emitting element having high electrical



energy utilization efficiency.